

To: Emily Anderson, Wild Salmon Center

From: Adam Wlostowski, PhD., Lynker

Subject: Comments on Pebble Project Final EIS

Date: August 7, 2020

1 Executive Summary

The Pebble Limited Partnership (PLP) is proposing to develop the Pebble copper-gold-molybdenum porphyry deposit, located in the headwaters of Bristol Bay, southwest Alaska. Proposed mining operations will generate over 52 million tons of waste rock, 75% of which is projected to be rich in sulfide minerals likely to generate acid and leach contaminants when exposed to the oxygen and water rich environment at the earth's surface (US Army Corps of Engineers, 2019)¹. If contaminated waters are transported to streams/groundwaters or improperly treated, they will degrade the biological integrity of aquatic ecosystems (EPA, 2014). This document presents an independent scientific review of mine site water quality risks presented in the Final Environmental Impact Statement (FEIS).

My review interrogates PLP's plan to mitigate mine site water quality risks, as documented in the FEIS. Specifically, the review is focused on the Water and Sediment Quality sections in the Affected Environment and Environmental Consequences sections of the FEIS and associated appendices (Section 3.18, Section 4.18, Appendix K3.18, and Appendix K4.18), the Project Description (Appendix N), and select water quality related citations therein. Additionally, my review assesses the extent to which water quality related comments raised during public comment on the Draft EIS (DEIS) were addressed by the FEIS. As such, this review also considers several requests for information (RFI) documents.

Three key criticisms summarize the review findings.

- 1. The FEIS underestimates acid generation and contaminant leaching potential of mine site wastes, increasing the risk that uncaptured seepage from wastes will adversely affect groundwater and surface water quality and overwhelm water treatment plants.**
- 2. Proposed waste rock characterization approaches will underestimate contaminant leaching potential of wastes. Waste rock misclassifications will cause acid generating and contaminant leaching material to be used as construction fill, increasing nonpoint source contaminant loadings.**
- 3. The waste rock and pyritic tailings have high acid-generation potential, yet the only mitigation measure proposed is submerging the wastes, which has been shown to be ineffective by PLP's own test results. Unlike most mines with similar wastes, no lime or neutralization addition is proposed for the wastes or the pit lake.**
- 4. The FEIS fails to include key contaminant sources in the water quality model, resulting in underpredicted contaminant concentrations in groundwater and surface water. Specifically,**

¹ Reported waste rock figures are from the Draft Environmental Impact statement. These figures have changed in the Preliminary Final EIS.

the water quality model completely ignores Tertiary waste rock, underestimates hydrologic fluxes from waste rock piles, and assumes unrealistically low leachate contaminant concentrations from quarried rock fill. Shortcomings in the water quality model increases the risk of under designing water treatment plants and underpredicting contaminant concentrations in sensitive ecosystems.

2 The FEIS underestimates acid generation and contaminant leaching potential of mine waste

PLP plans to generate an estimated 93 million tons of waste rock before and during construction and mining (US Army Corps of Engineers, 2020a)². Some unspecified fraction of this waste is likely to generate acid and leach contaminants. Upon excavation, waste rock will be deposited *subaerially* (open to the atmosphere in large stockpiles and embankments) and *subaqueously* (submerged in standing water) throughout the site. Accurately predicting waste rock acid generation and contaminant leaching potential in these environments is necessary to develop a robust water and waste management plan that will prevent contaminated contact water from impacting streams and other sensitive ecosystems. **My review found that the FEIS underestimates acid generation and contaminant leaching potential by misinterpreting geochemical test results, ignoring relevant geochemical processes, and misleading readers on likely quantities and varieties of waste rock likely to be generated.**

A brief recap of waste rock fate at the Pebble Project site is necessary for context. During construction and mine operations, PLP will generate an estimated 93 million tons of waste rock (US Army Corps of Engineers, 2020a). The FEIS conceptually divides waste rock into two categories - potentially acid generating (PAG) and non-potentially acid generating (non-PAG). PLP plans to store PAG waste rock subaerially in large stockpiles adjacent to the pyritic tailings storage facility (PTSF) for an estimated 1.5 years following excavation. After 1.5 years, supernatant water in the PTSF is projected to submerge PAG waste rock, storing it in a subaqueous environment until closure. Upon closure, PLP proposes to move PAG waste rock (and tailings) from the PTSF back to the open pit, where it will be subaerially and then gradually submerged with water and remain in subaqueous storage in perpetuity. Although much of the waste is highly acid generating, PLP proposes no addition of lime or other material to help neutralize the acid.

PLP proposes to use non-PAG waste rock to construct earthen embankments for the bulk tailings storage facility (BTSF) (US Army Corps of Engineers, 2020a). As such, non-PAG waste rock will be stored subaerially in the BTSF embankments in perpetuity.

PLP succinctly summarizes the waste rock handling plan in section 3.2.3 of the Project Description:

“Waste rock is mined material with a mineral content below an economically recoverable level that is removed from the open pit, exposing the higher-grade production material. Waste rock will be segregated by its potential to generate acid.

² 93 million tons is the sum of waste rock quantities in Tables 3-2 and 3-3 (pre-production and production) of Appendix N of the Final EIS

NPAG and non-ML waste rock may be used for embankment construction.” – Appendix N, section 3.2.3, FEIS (US Army Corps of Engineers, 2020a)³

2.1 Waste rock contaminant flushing events are ignored

The sulfide minerals in subaerially exposed waste rock will oxidize and form highly soluble metal sulfate minerals (Jambor, 2000; Nordstrom, 1982; Nordstrom & Alpers, 1999). When waste rock is stored subaerially in stockpiles or embankments, it is exposed to periodic flushes of rainwater and snowmelt. Such periodic flushing events can rapidly dissolve and transport contaminants from waste rock, affecting the quality of downgradient waters. **The FEIS ignores the potential for periodic flushing events by disregarding early-time results in the kinetic geochemical tests. This oversight results in a likely underestimation of nonpoint source contaminant loads and increases the risk of contact water affecting streams and groundwaters.**

SRK (2018) used humidity cell test (HCT) data to estimate subaerial contaminant leaching rates from waste rock and quantify leachate concentrations for a variety of analytes and sources⁴. Knight Piesold (2018b & 2018a) then used HCT-derived source concentrations as inputs to the site water quality model. The water quality model was recently revised from the Draft to Final EIS in Knight Piesold (2019). Results of all HCTs are found in (PLP, 2018, Appendix 11D-F).

Generally, SRK (2018) used HCT results to estimate laboratory contaminant leaching rates (i.e. weathering rates), which were then scaled (adjusted) to estimate field weathering rates (SRK, 2018 p.12). According to SRK (2018, p. 12), laboratory weathering rates were derived from HCTs through the following steps (direct quote):

1. *Release rates per week (mg/kg/week) are calculated for each parameter for each week based on the concentration (mg/L), leachate volume (L/week) and mass of the sample (kg).*
2. *The end of the initial flush is estimated from the sulphate leaching trend*
3. *The average rate following the end of the flush is calculating for each test*
4. *95th percentile rates are calculated separately for each major rock type category and grouped by pH of the leachate.*

This sequence of steps ignores key components of HCT test results. Step 2 of the above process states that “initial flush” HCT data are ignored by SRK (2018). The initial flush describes the early period of a humidity cell test when soluble salts are flushed out of the rock matrix (Maest & Nordstrom, 2017). Although ASTM methods advise practitioners to use caution in interpreting data from the first few weeks of testing (ASTM, 2013), discarding these data discounts the importance of periodic flushing events likely to occur repeatedly under field conditions (Maest & Nordstrom, 2017).

The initial flush in HCTs is representative of periodic flushing events commonly observed in the field. As discussed by Nordstrom (2009) and citations therein, rainfall or snowmelt events following prolonged dry periods dissolve soluble salts from the surface mine wastes, resulting in transiently elevated leachate concentrations (e.g. Vriens et al., 2019). Salts from sulfidic mine wastes, like those associated with the Pebble Project, commonly contain sulfate derived from the oxidation of sulfide minerals in the

³ NPAG is an acronym for Non-Potentially Acid Generating and non-ML is an acronym for non-Metal Leaching.

⁴ This is cited as SRK 2018a in the Final EIS, Appendix K3.18, Appendix K4.18, and Section 3.18

wastes. Weathering of other minerals can also form chloride or carbonate salts, depending on the composition of the rocks or waste. The basic mechanism of rain and snowmelt water flushing salts and enriched pore waters from the shallow subsurface is a widely recognized hydrogeochemical phenomena in natural and impacted environments (Foster & Walling, 1978; McKnight et al., 2007; Olshansky et al., 2018; Rice et al., 2004).

A recently published long-term study of waste rock leachate chemistry shows how periodic flushing events drive seasonal pulses of contaminants from the wastes (Vriens et al., 2019). Additionally, this study concluded that small scale lab and field tests, such as HCTs and barrel tests, are poor representations of contaminant leaching observed in full-scale waste rock piles. Contaminant leaching rates from waste rock piles in the field depend on metal and sulfate release from the sulfate salts, element retention due to sorption, precipitation of secondary minerals, and internal drainage and mixing processes. The findings of Vriens et al. (2019) contradict the assumptions made by PLP, which ignore transient element release, retention, and re-release processes. Moreover, this new work questions the overall approach used by PLP, whereby field-scale leaching is projected from small-scale tests that do not consider important hydrologic and hydraulic properties of waste rock piles.

During dry periods, evaporation and sublimation cause salt crusts to form on rock and waste surfaces. Periodic infiltration events rapidly dissolve salts, pushing a pulse of chemically enriched water through the rock or waste matrix (McKnight et al., 2007; Nordstrom & Alpers, 1999).

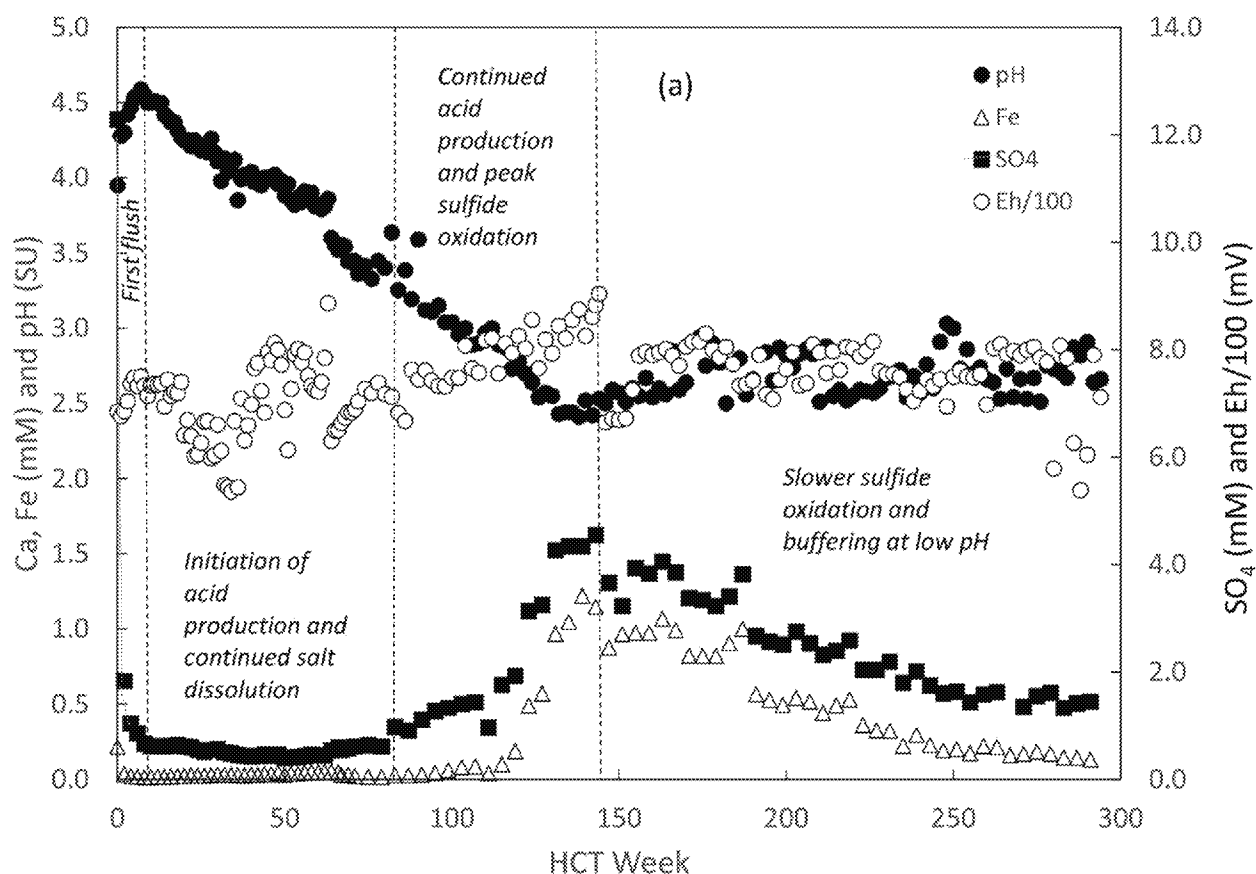


Figure 1. HCT results from Pebble Project sample 3069-0927-0947, granodiorite, trickle leach, 2.44% sulfide. Image taken from (Maest & Nordstrom, 2017). The first flush period extends from the test initiation through week ten. Data were transcribed from

In the context of HCTs on waste rock samples from the Pebble Project, the first flush generally occurs over the first several weeks, when the dissolution of sulfate salts results in elevated concentrations of iron, sulfate, and other constituents (Figure 1). Copper and other metals are also often elevated in first flush releases (PLP, 2018, Appendix 11D-F)

Data shown in Figure 1 were taken from Appendix 11D of the Supplemental Environmental Baseline Data (SEBD) Report (PLP, 2018). Visualizations of HCT test results on Pre-Tertiary waste rock are shown in Appendix 11F of the SEBD. A plot showing sulfate release rate with time is copied directly from Appendix 11F of the SEBD and shown in Figure 2. Results for sample 3069-0927-0947 (red triangles) show an initial peak sulfate release rate of approximately 500 mg/kg/wk. Sulfate release rates drastically decline between test initiation and day 500 before rising again to a secondary peak rate of 206 mg/kg/wk near day 1000. The average sulfate release rate gleaned by PLP for test results for sample 3069-0927-0947 is 43 mg/kg/wk (PLP, 2018, Table 11-12⁵), approximately 12 times lower than the first flush rate and 5 times lower than the secondary peak rate at day 1000.

⁵ Summary of Average Release Rates for Humidity Cell Kinetic Tests, Pre-Tertiary Samples, Pebble East and West Zones, sample ID 3069-0927-0947. The reported average release rates are calculated *after* early-time data have been masked out of the analysis. PLP never specifies the timing of the end of the initial flush for sample ID 3069-0927-0947 (or any sample) making it difficult to know which observations are used to calculate average release rates.

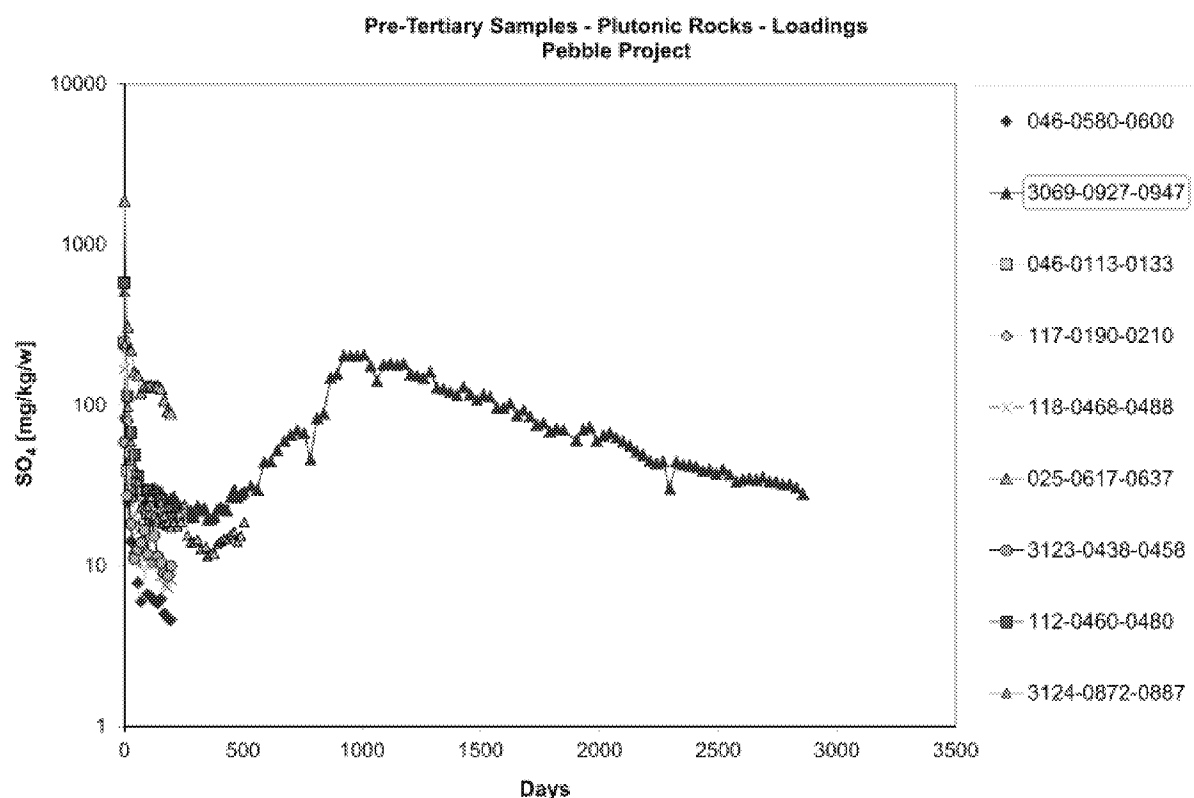


Figure 2. Sulfate release rates from humidity cell tests conducted on Pre-Tertiary waste rock samples. This figure was copied directly from Appendix 11F of the Supplemental Environmental Baseline Data Report, Graph 10 of 38. The data for sample 3069-0927-0947 are the same data that appear in Figure 1.

Periodic flushing events, like those observed in HCTs, are observed in PLP's field barrel tests conducted using waste rock from the Pebble West Zone, which is part of the deposit proposed to be mined. Specifically, test results for waste rock samples ARLB001 & ARLB002 show periodic spikes in sulfate concentration likely stemming from periodic infiltration events (PLP, 2018, Appendix 11I, section 11.7.1.3.3 & Figure11-31). Moreover, sulfate peaks in field barrel tests coincided with lower pH conditions and peaks in aluminum, cadmium, copper, iron, selenium, nickel and other constituents (PLP, 2018 Appendix 11I). PLP's own field barrel test results show that flushing events mobilize solutes under field conditions.

Samples ARLB001 & ARLB002 (PLP, 2018, Appendix 11I) are different than the other field barrel tests because acidic conditions prevailed at the onset of the test. These two samples had the highest sulfide percentages and lowest initial pH of all field barrel tests (PLP, 2018, Table 11-25). These tests indicate that if the waste has already produced acid it may be more susceptible to periodic solute flushing and continued acid production. Indeed, revised source terms in the mine site water quality model concede that ~37% of the PAG waste rock will be acidic immediately upon excavation (Knight Piesold, 2019, Appendix D2). Results for HCTs on Tertiary rocks, which are generally non-PAG, also show pronounced first-flush solute increases in sulfate, metals, and other constituents (SEBD Appendix 11E, Graphs 2-37 of 37).

Like the DEIS, the FEIS does not include early-time flushing data observed in HCTs. Consequently, the FEIS ignores the effects of solute flushing events from subaerial waste rock piles (especially PAG waste rock in the PTSF) and pit walls, undermining well-established science and the results of Pebble Project field barrel tests. The site water quality model does not include results from initial flushes in their source terms for infiltration and runoff from waste rock (Knight Piesold, 2019, Appexndix A), and therefore the effective solute loading associated with these flowpaths is underestimated.

Additionally, SRK (2019) responded to a related request for analysis from the U.S. Environmental Protection Agency (EPA) for additional analysis regarding the significance of first-flush effects:

“Analysis that demonstrates that the currently developed SRK source terms are reasonable and representative compared to using the “first flush effect” from humidity cell testing.” – Request 3a

In response, SRK (2019) argues against the need to consider first flush effects. Specifically, SRK remarks:

“In laboratory tests, the ‘first flush’ effect is often attributable to leaching of oxidation products that had accumulated before the sample was tested while the sample was in storage as core or crushed prior to analysis. This flush may be an artefact [sic] of the pre-test conditions and therefore should not be applied directly to predicting performance under field conditions.” - (SRK, 2019, section 2.3.1)

This response ignores meteorological conditions that generate first flush releases in waste piles, and continues to disregard periodic flushing of acidic water, metals and other solutes observed in comparable field environments (Maest & Nordstrom, 2017; Nordstrom, 2009) and PLP’s barrel test results. No additional analysis was provided to support this conclusion.

Changes from DEIS to FEIS:

- No changes have been made to incorporate the influence of periodic flushing events on site water quality.
- PLP continues to ignore early-time HCT data and barrel test results that show how periodic flushing drives contaminant leaching and acid generation.

Recommendation(s):

- Revise the water quality model terms representing the concentration of waste rock and pit wall runoff and infiltration.
- Specifically, revise flow path #78 (and other similar flowpaths) in the site water quality model (Knight Piesold, 2019, Appendix A, Table A.1), to include periodic flushing events.
- Use early-time HCT data and barrel test results to quantify the additional solute loading associated with flushing events.

2.2 Statistical interpretation of kinetic geochemical test data is misleading

The statistical interpretation of HCT data discounts repeated dissolution and peak oxidation events that drive high solute release rates under field conditions, leading to an underestimation of nonpoint source contaminant loads. According to steps 3 & 4 in SRK’s process of estimating laboratory leaching rates (SRK, 2018, p. 12), the average of post first-flush release rates is calculated for each constituent

and the 95th percentile of average rates is taken across all HCTs. This statistical interpretation yields an conservative-sounding estimate of leaching rates, but it is misleading. By calculating the 95th percentile of *average* post-flush conditions, SRK either explicitly removes or discounts higher release rate data points.

Averaging over post-flush data ignores useful transient information in HCT results. For example, Figure 1 shows a progressive rise in sulfate and iron concentration, coincident with a steady drop in pH between weeks 75 and 100 for sample 3069-0927-0947 (sulfate data are also presented in Figure 2). As shown by Maest & Nordstrom (2017), this is the time of peak sulfide oxidation and continued acid production. During this time, the maximum sulfate release rate is 206 mg/kg/wk, or five times higher than the post-flush average release rates. By averaging over data following the first-flush, transient spikes in solute release rates are discounted, leading to a low-end estimate of weathering rates. Moreover, as argued by Maest & Nordstrom (2017), it is unreasonable to assume that HCT data are indicative of steady-state field conditions, not least because steady-state field conditions do not occur. Field conditions are intrinsically unsteady.

Comments by Maest (2019) on the DEIS requested that the statistical procedure behind quantifying release rates from HCT data be accurately represented in the FEIS as “95th percentile of average concentrations.”

SRK (2019) responded to a related request from the U.S. EPA:

“An analysis demonstrating that the 95th percentile data used in the SRK (2018f) source term evaluation memorandum captures the variability of the PWZ data if the combined PWZ-PEZ data set is used.” – Request 1b

This comment partially reflects concerns raised here regarding using the 95th percentile of average release rates observed in HCTs. However, the response from SRK (2019) does not address the issue. SRK remarks:

“Upper level statistics (95th percentile) were used throughout the source term method (see Table 5 in SRK (2018) rather than a representation of central tendency (e.g. median, mean) to ensure that the overall input into the model represented highest likely concentrations that might need to be treated. This ensures that appropriate water treatment technologies were selected to consider all possible parameters, which was the purpose of the model. The use of upper level statistics also addresses uncertainty in general about the overall size of the dataset and the decision about which tests should be included (entire, or a subset). An additional consideration is that rates derived from humidity cells are only the first step in the calculation of source terms. The calculations also consider the solubility of individual parameters which are based on upper level concentrations at the lower end of expected pH values.” - (SRK, 2019, section 2.1.1)

This response provides no clarification that “upper level statistics” are taken from *average* release rates and continues to mislead the EIS process with the false notion that extremely conservative weathering rates are being used to estimate contaminant concentrations in streams and groundwaters.

Changes from DEIS to FEIS:

- No changes have been made in the FEIS to clarify that weathering rates are calculated from the 95th percentile of average release rates or to use a more appropriate estimate of weathering rates that captures events known to occur repeatedly in the field.

Recommendation:

- Revise Appendix K4.18.1 of the FEIS to clearly state that release rates are the 95th percentile of average release rates, not 95th percentile values.
- Create a table displaying the start and end time of the period over which release rates were averaged, the average value used, and the range of rates over the period - for each HCT. This time period is conceptually referred to by SRK as “*following the end of the flush*” (2018, p. 12). Without a clearly defined time window, it is unclear which test data were considered and which were ignored.

2.3 Field contaminant leaching rates are underestimated

SRK used adjustment factors to approximate field leaching rates from laboratory-derived leaching rates. The adjustment factors used by SRK account for oxygen exposure, temperature, particle surface area, and water contact (SRK, 2018, p.12). SRK applied the same factors across all lithologies and analytes. The only citation provided to support this approach is Day et al. (2014), a non-peer-reviewed conference presentation. Overall, adjustment factors reduce laboratory-derived rates by a factor of five. **This overly simplistic approach for translating laboratory results to field predictions results in an underestimation of contaminant releases from waste rock.**

Using generic lab-to-field weathering rate adjustment factors across lithologies and waste types runs contrary to scientific understanding. A study of lab-to-field weathering rate adjustment factors conducted by Lapakko & Olson (2015) showed that adjustment factors can vary by a factor of 20 for one constituent at a single site. Maest & Nordstrom (2017) provide further discussion on the issues associated with generic adjustment factors. Generally, weathering rate adjustment factors are highly uncertain, and applying generic adjustments across lithologies and sites yields a dangerously narrow estimate of weathering rates under field conditions. Previous comments on the DIES from Maest (2019) recommended reevaluating the approach used to estimate field rates from laboratory rates.

Changes from DEIS to FEIS:

- No changes have been made in the FIES to the use of generic adjustment factors to estimate field weathering rates from laboratory rates.

Assumption consequence:

- Simple adjustment factors applied uniformly across lithologies and analytes results in overly uncertain estimates of field weathering rates (though this uncertainty is never quantified), thereby increasing the risk of under designing site water treatment facilities by not accounting for uncertainties.

Recommendation:

- Use kinetic geochemical test data (laboratory HCTs and field barrel tests) to quantify the uncertainty in scaling factors to convert laboratory to field rates. Each lithology warrants its own

uncertainly analysis. Take the 5th percentile of the scaling factor uncertainty distribution (i.e. the lowest foreseeable scaling factor values) and apply them to laboratory rates to estimate field rates.

2.4 Acid generation lag times are underestimated

Carbonate mineral contents in PAG rock are too low to effectively delay the onset of acidic conditions. SRK (2018) claims that acid-neutralizing carbonate minerals will delay the onset of acidic conditions in PAG rock.

“The geochemical characteristics of the PAG waste rock have been determined through static testing, laboratory kinetic testing and site kinetic testing. This testwork [sic] has confirmed that oxygenated PAG rock generates acidic contact water but that the onset of acid weathering conditions is delayed by the presence of acid-neutralizing carbonate minerals.” - (SRK, 2018, p. 5)

However, the results of PLPs own geochemical testing reveals that the carbonate mineral contents in PAG rock are too low to effectively delay the onset of acidic conditions. **Overestimating the potential for carbonate minerals to delay the onset of acidic conditions runs the risk of generating acidic conditions in tailings storage and water management facilities before predicted and falsely assumes no other mitigation measures will be necessary during mine operations.**

Calcite (CaCO_3) and magnesium carbonate (MgCO_3) are the most effective carbonate minerals in terms of acid neutralization, and siderite (FeCO_3) and silicate minerals will not effectively neutralize highly acid generating wastes such as those at the Pebble Project (Balistrieri et al., 1999; Plumlee, 1999). The results of PLPs own static geochemical testing show that pre-Tertiary (PAG) rocks have very few carbonate minerals. These results are found in Tables 11-17 and 11-18 of the Environmental Baseline Data Report, Chapter 11 (PLP, 2011). X-ray diffraction analysis in Table 11-18 reveals that carbonate minerals account for 0 - 4.5% of samples by weight and only trace quantities of carbonates were detected in most samples. In addition, these results do not distinguish between calcium/magnesium carbonates, which will neutralize acid and siderite, which will produce acid when dissolved; the presence of siderite in Pre-Tertiary waste rock samples is noted in the SEBD (p. 14). SRK maintains that carbonate minerals will delay the onset of acidic conditions, despite a paucity of carbonate minerals.

Calculations in section 11.7.1.7 of the EBD (p. 11-54) assume lag times are directly related to a rock's effective neutralization potential (NP_{eff}). Effective neutralizing potential is the neutralizing potential provided by the dissolution of calcium and magnesium carbonate minerals, which are much more effective at neutralizing acid than silicate minerals (Jambor, 2000). SRK determined that any sample with <10 kg CaCO_3 /ton is ineffective in neutralizing acid:

“It appears that NP up to 10 kg CaCO_3 /t is ineffective. Thus, the ineffective NP of 5 kg CaCO_3 /t (as discussed in Effective Neutralization Potential Indicated by Static Test Data in Section 11.7.1.3) should be raised to 10 kg CaCO_3 /t.” - (PLP, 2011, p. 11-53)

In Table 11-11 of the SEBD this rule appears to have been either changed or ignored because lag times are calculated for six samples with $\text{NP} < 10 \text{ kg } \text{CaCO}_3/\text{ton}$. Calculated lag times for these samples range from 5 to 13 years. How can lag times be greater than zero if there is no effective neutralizing potential?

By declaring some samples as being ineffective in neutralizing acid, then it should follow that some waste rock is likely to generate acid.

The revised mine site water quality model includes a new source term for PAG waste rock in the PTSF that will immediately generate acid (no lag time for “leached” waste rock). The new source term is described in Appendix D2, Section 4.1 of the Water Balance and Water Quality Model Report (Knight Piesold, 2019):

Two new source terms were developed to describe the behavior of potentially acid generating (PAG) waste rock disposed in the Pyritic Tailings Storage Facility (PTSF) before it is submerged. These replace the single source term for the PTSF in SRK (2018).

Based on lower NP in near surface naturally-weathered “leached” rock, one source term was assumed to be acidic and have chemistry indicated by the database of porphyry mines in the Canadian cordillera (see Section 3.3.1 in SRK (2018)). Deeper PAG bedrock with higher NP was assumed to be non-acidic and was similarly assigned chemistry using the porphyry database. Based on mine plan information provided by PLP, the proportions of near surface leached and deeper PAG rock were 37:63. The source terms are expressed as concentrations (mg/L).

Due to the separation into two source terms, there is no specified assumption for the time to submerge the waste rock which prevents the onset of acid generation. Leached waste rock is already acidic whereas PAG waste rock would likely take well over a decade to acidify.

By including a new source term in the water quality model, PLP admits that some PAG waste rock will release contaminants into the PTSF. However, their reliance on the “porphyry database” to specify these sources is questionable (Knight Piesold, 2019, Appendix D2, Section 4.1).

- First, using the porphyry data base effectively negates thousands of PAG waste rock HCT results in the Pebble Project Environmental Baseline Data Report. Why would SRK advocate using off-site data in lieu of site-specific data?
- Second, the porphyry data base describes the chemistry of diluted waste rock runoff and leachate (SRK, 2018a, Section 3.3.1, p. 13)⁶. Using these data as a source term in a water quality model risks double counting dilution, yielding unreasonably low concentration estimates.
- Third, the source term modification appears to have little or no effect on modeled PTSF chemistry, even though 37% of the PAG waste rock will be immediately acidic upon excavation.
- Fourth, to estimate solubility controls, the highest dissolved concentrations should be used rather than any statistical measure (e.g., 95th or even the 99th percentile). This is because the dissolved concentrations reflect the total solubility of whatever is dissolving in the test at the pH and other test conditions of the sample. If the solubility were lower, the concentration would be

⁶ The proprietary porphyry database used by SRK contains *drainage* chemistry data – i.e. the concentration of waters draining from waste rock piles. This drainage water has already been diluted. So, using *drainage* chemistry from the porphyry database to determine source term concentrations at the Pebble Mine site will end up double-counting dilution in water quality models.

lower. SRK uses the 95th percentile for the barrel test results, which underestimates maximum concentrations of many constituents (As, Cd, Cu, Fe, Mn).

- Finally, because the barrel test results are not representative of potential field concentrations at scale, the measured barrel concentrations underestimate field concentrations from large waste deposits (Vriens et al., 2019). Leachate contaminant concentrations are a function of the amount of material in the test (up to solubility limits); this is why test rates, rather than leachate concentrations, are used to predict concentrations expected in the field. Specifically, concentrations are estimated as the product of the contaminant leaching rate (mg/kg-waste/week) and the total mass of waste (kg). PLP caps magnitude of the product with solubility caps that are not comparable in terms waste mass. For example, Vriens et al. (2019) observe high sulfate concentrations in waste pile leachate – over 10,000 mg/L. And using site-specific data, measured copper concentrations in the acidic, Pre-Tertiary field barrel test ARLB001, had copper values ranging from 2,370 to 63,800 mg/L, with many values over 10,000 mg/L (SEBD, Appendix 11I). Yet the copper concentration cap used for acid pH values (3 to 4) is only 640 mg/L (SRK, 2018a, Table 2).

SRK also predicts lag times from average stable sulfate release rates observed in HCTs:

“Stability was defined either as a break in the release rate trend whereby the overall change lessened or by a point in time when the release rates no longer increased or decreased on average.” –Pebble Project Environmental Baseline Data Report, p. 11-16

Visually, “stable” data would seem to correspond to HCT data from the very end of an HCT when there is relatively little variability in sulfate release. In the test results shown in Figure 1 and 2, this would likely correspond to data beyond week 200. It is hard to say for sure because neither the DEIS nor the FEIS report the period of each HCT considered “stable.” Regardless, the selected stable times are not representative of salt leaching or peak sulfide oxidation, which both occur earlier in the tests (Maest & Nordstrom, 2017).

Changes from DEIS to FEIS:

- PAG waste rock source terms in the water quality model were revised to account for some of the waste rock being immediately acidic upon placement in the PTSF. This changes is discussed in Knight Piesold (2019), Appendix D2, Section 4.1.

Assumption consequence:

- Over-estimating lag times risks wastes going acidic before or during operations or early closure.

Recommendation:

- Conduct an analysis to assess how uncertainties in lag-time calculations may affect PAG waste rock source terms in the site water quality model.
- Use site-specific kinetic test data to estimate waste rock runoff/leachate concentrations, not the porphyry database. Larger-scale waste rock field tests should have been conducted but were not.

2.5 Subaqueous leaching potential is ignored

The FEIS assumes that potentially acid generating waste rock and tailings materials will be non-reactive if submerged in tailings impoundments or the open pit. However, the results of PLP’s own experiments, analytical reasoning, and the outcomes of similar historical mining projects contradict this assumption.

Assuming subaqueously stored tailing and waste rock will not leach anything is concerning because it ignores a likely source of contaminant loading, especially in the PTSF and open pit. Moreover, not accounting for this source term results in an underestimation of contaminant concentrations reporting to site water treatment plants.

Models supporting the FEIS assume PTSF wastes (pyritic tailings and PAG waste rock) do not continually leach metals and acid. As stated in Chapter 2 p. 2-26 of the FEIS (US Army Corps of Engineers, 2020b):

“The entire pyritic TSF, including both the tailings and waste rock, would be continually inundated with water to prevent these materials from oxidizing and generating ARD” – FEIS Chapter 2, p. 2-26

Or more directly stated by SRK:

“Sulfide tailings were assumed to be non-reactive under fully saturated conditions. No source term is assigned [in the site water quality model]” - (SRK, 2018a, p.18)

Indeed, the site water quality model assumes that once submerged, PAG waste rock and pyritic tailings do not leach *any* acid or contaminants into solution (Knight Piesold, 2018b). PAG waste rock only contributes initially “flushed” subaerial weathering-products upon submersion, and tailings slurry is treated as a point load. The site water quality ignores the potential for submerged mine waste to leach any contaminants (Knight Piesold, 2019, Appendix D2, section 4).

By ignoring the potential for subaqueous leaching, PLP under-predicts contaminant loads from mine sources, which leads to erroneous water quality predictions. **PLP therefore risks under designing mine water treatment facilities relative to site needs⁷**. This risk is well stated by Knight Piesold:

“The water treatment plants are being designed by others based on the flow rate results of the water balance model and the water quality predictions from the WQ model.” - Knight Piesold (2018b)

Generally, subaqueous leaching is acknowledged as a non-negligible solute source in the scientific literature. Subaqueous leaching was observed at the Sleeper pit lake in Nevada (Newman et al., 2019). This study concluded by stating. *“If [subaqueous leaching processes] are ignored in modeling and permitting studies, proponents risk underestimating the concentrations of important solutes (e.g., sulfate and metals) in future lakes, which may increase the time and cost of ultimate closure actions.”* Additionally, (Lapakko, 1994) reached a similar conclusion after observing continued acid generation and metal leaching from subaqueously disposed wastes.

Other agencies expressed concern about the proposed subaqueous disposal of PAG rock and tailings. Specifically, a comment in Appendix D, Comment Analysis Report, of the FIES states:

*“Concerns were expressed that the potential for acid rock drainage (ARD) is not adequately assessed, that the timeframe for generation of acid may not be reflective of actual conditions, and that the effects and duration of ARD in the future will be greater and much longer than is currently described in the EIS. **Additionally, concern was expressed that tailings stored subaqueously still have the potential to continue to oxidize and generate ARD, and this is neglected in the analysis.** Comment stated these ARD conditions will lead to impacts to surface water quality.” – FEIS, Appendix D, p. D-263⁸.*

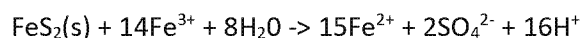
In response, additional text was added in Section 4.18.4.1, p. 4.18-16, of the FEIS (US Army Corps of Engineers, 2020c) explaining how submersion will reduce contact with air and therefore oxidation. This is simply a narrative defense and no additional data, analysis, or citations are provided to assess the

⁷ Water treatment plants are already designed to operate at capacity margins and cycle contaminants in a closed-loop system, leading to progressive chemical enrichment of influent water (Sobolewski, 2020). Unforeseeably high solute concentrations in influent waters can overwhelm treatment capabilities and increase the risk that effluent waters will exceed state and federal water quality standards.

⁸ Bold face added by A. Wlostowski for emphasis.

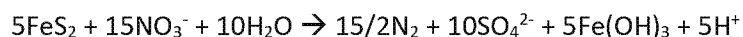
likelihood of turbulent mixing and/or groundwater seepage disturbing anoxic conditions, or oxidation occurring in an anaerobic environment.

Subaqueous (anoxic) leaching can occur and is well documented in other studies/sites. In the absence of oxygen and at low pH, ferric iron is an extremely effective pyrite oxidant. This reaction yields ferrous iron, sulphate and acid (Gammons et al., 2009; Singer & Stumm, 1970):



At low pH (< 4) ferric iron exists and may be produced by the microbially-mediated oxidization of ferrous iron (Gammons et al., 2009). Indeed, subaqueous pyrite oxidation can facilitate metal leaching in submerged PAG waste rock and tailings, as shown by Vigneault et al. (2001). While ferric iron is likely to be a finite oxidant because it will eventually be exhausted in a truly anoxic environment, it remains a critical and relevant oxidant for the Pebble Project impoundments that hold pyritic wastes. The concept of ferric iron oxidization of pyrite is well established in the scientific literature and warrants consideration by PLP and the USACOE in the EIS process.

Nitrate is also an effective oxidant capable of driving subaqueous pyrite oxidation at the Pebble Site (Hayakawa et al., 2013):



Because blasting agents are rich in nitrate, it is reasonably foreseeable that waste rock and tailings storage facilities and the pit lake will contain the nitrate required to drive pyrite oxidation reactions. Indeed, other studies observe high nitrate concentrations within and proximal to pit lakes and tailings impoundments. Golder Associates (2020) shows nitrate concentrations between 1 – 18 mg/L (as N) in wells immediately downgradient of the Kettle River tailings impoundments associated with the Buckhorn Mountain Mine in Washington, USA. The same report also documents nitrate concentrations between 3.5 – 8 mg/L (as N) in tailings impoundment underdrain waters at the Kettle River facility. Elsewhere, at the Jamestown Mine in California, Kuipers et al. (2006) report nitrate concentrations up to 600 mg/L (as N) downgradient of waste rock and tailings facilities, likely derived from blasting agents. Moreover, Gammons et al. (2009) reports nitrate concentrations up to 83 mg/L in a pit lake at Anchor Hill, South Dakota and states, “*Some pit lakes may initially have high nitrate concentrations from explosive residue ...*”.

PLP’s own subaqueous column tests highlight the potential for subaqueous leaching (PLP, 2018). Initially acidic samples became even more acidic in subaqueous column tests. These samples also continued to leach copper and arsenic (PLP 2018, Appendix 11, samples #s 3124-1088-0209 & 3069-0927-0947). The results of PLP’s tests clearly show that waste rock can continue to generate acid and leach metals if it is already acidic when submerged (Figure 3). Subaqueous acid generation and metal leaching is corroborated by Lapakko et al. (2013) who observed a gradual decline in pH and increasing copper

concentrations over four years in subaqueous column tests on unmitigated waste rock samples.

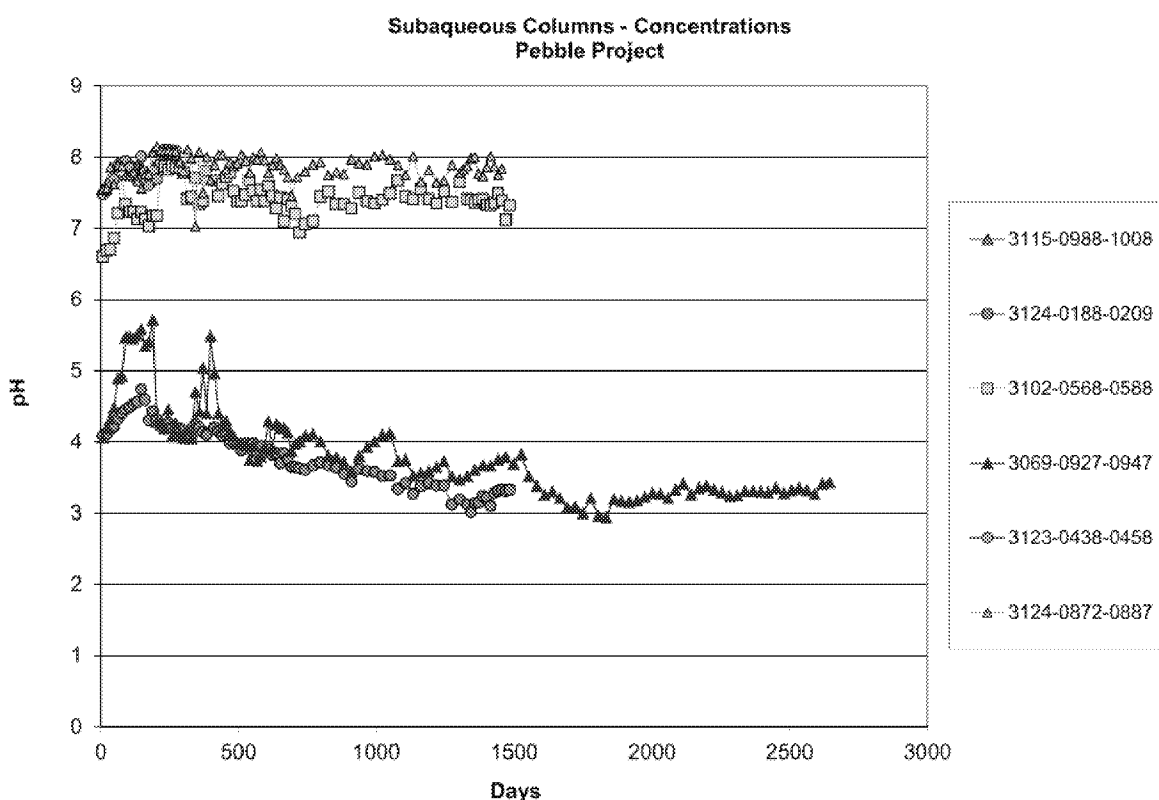


Figure 3. Subaqueous column test results show continued acid generation from initially acidic samples. Figure taken from Appendix 11G, Graph 1 of 38 in the Pebble Project Environmental Baseline Data Report.

Indeed, the submersion of already-acidic waste rock is extremely likely at the Pebble site. As explained by (SRK, 2018a), subaerial weathering will occur prior to submersion:

“The planned management approach is to dispose PAG waste rock sub-aqueously in the PTSF. Operationally, this would likely occur by placing the rock above the water level in the PTSF with subaqueous conditions resulting as the water level rises into the waste rock. The rock above the water level will weather under subaerial oxygenated conditions before it is inundated” (SRK, 2018a)

Moreover, changes made to the water quality model from the DEIS to the FEIS clearly acknowledge that some PAG waste rock will be immediately acidic upon disposal in the PTSF, even under submerged conditions (Knight Piesold, 2019, Appendix D2, Section 4.1). If some of the waste rock will be acidic upon submersion in the PTSF, then additional analysis should be conducted to account for the risk of subaqueous leaching observed in PLP’s own submerged column tests.

Changes from DEIS to FEIS:

- No quantitative changes were made to consider the potential for subaqueous leaching in the PTSF or the open pit.

Assumption consequence:

- Ignoring subaqueous leaching risks underestimating solute loads reporting to site water treatment plants. As summarized by Sobolewski (2020), the proposed waste water treatment plants will be ill-equipped to treat the influent load assumed by the FEIS. Unforeseen increases to site water contaminant concentrations will further stress the already taxed and untested water treatment system.

Recommendation:

- Recalculate source terms for submerged PAG materials (tailings materials and PAG waste rock) in the PTSF during operations and the open pit during closure to acknowledge the potential for the continued leaching shown in geochemical tests.
- Specifically, consider the potential for ferric iron and nitrate driven oxidation of pyritic wastes.
- Investigate the mixing environment of the PTSF and pit to quantify the likelihood of dissolved oxygen interacting with submerged wastes.
- Consider treating waste rock and tailings with lime or other alkaline additions to reduce acid generating potential.

2.6 PAG Waste rock capacity in the PTSF has increased dramatically in the FEIS but embankment heights are lower

Changes to the Project Description (Appendix N) between the DEIS and FEIS increase estimates of total waste rock production but do not state how much waste rock will be PAG versus non-PAG. **This is concerning because the quantity and characteristics of waste rock are needed to accurately predict contaminant loads from waste rock.**

A comparison of waste amounts, impoundment capacities, and PTSF embankment heights is presented in Table 1. The DEIS gives a breakdown of PAG and non-PAG waste rock in Table 3-3 of the Project Description (Appendix N; US Army Corps of Engineers, 2019a), estimating that during production approximately 75% of the waste rock (39 million tons) will be PAG. The FEIS in a similar table (also Table 3-3 in Appendix N of the FEIS) does not give a breakdown of PAG vs. non-PAG waste rock during pre-production or production. It also estimates a lower amount of overburden (38 million tons in the FEIS vs. 68 million tons in the DEIS) and a higher amount of waste rock (82 million tons in the FEIS vs. a total of 52 million tons in the DEIS) during production, implying that 30 million tons of overburden have now been classified as waste rock in the FEIS. The FEIS also seems to imply that all waste rock extracted during production is PAG. As shown in Table 1, the PAG waste rock capacity of the PTSF has increased from 50 million to 93 million tons in the FEIS. However, the embankment heights for the PTSF have somehow decreased (Table 1). No explanation for the change is provided, and clearly an additional 43 million tons of waste rock will not fit in a smaller impoundment. Changes in the areal extent of the PTSF are not described.

Table 1. Changes in the Project Description, Appendix N, between the DEIS and FEIS.

Classification	Source	DEIS	FEIS	Comments
Pyritic tailings in PTSF/capacity (tons)	Table 3-1	155,000,000	155,000,000	Pyritic tailings capacity is the same.
PTSF waste rock capacity (tons)	Table 3-1 (DEIS, App. N); App N, p. 1 (FEIS and DEIS)	50,000,000	93,000,000	43,000,000 more tons of PAG WR capacity in FEIS; looks like they're counting all pre-production and production WR in here
PTSF South embankment (height) (ft)	Table 3-1	305	215	The PTSF WR capacity has increased by 43 million tons, but the heights of all the embankments have decreased!
PTSF North embankment (height) (ft)	Table 3-1	425	335	
PTSF East embankment (height) (ft)	Table 3-1	315	225	
Preproduction phase PAG waste rock (tons)	Table 3-2	11,600,000	11,000,000	Just called "waste rock" in FEIS - not designated as PAG
Production phase overburden (tons)	Table 3-3	68,000,000	38,000,000	30,000,000 fewer tons in FEIS - shows up in "waste rock"
Production phase NPAG waste rock (tons)	Table 3-3	13,000,000	82,000,000	PAG vs NPAG not distinguished in FEIS; 30,000,000 tons more WR in PFEIS ("converted" from overburden - see above)
Production phase PAG waste rock (tons)	Table 3-3	39,000,000		

These changes are concerning because waste management plans, especially sizing of the PTSF, require reasonable estimates of how much PAG waste rock will be generated. Also, the quantity of Tertiary waste rock (non-PAG) to be generated is unknown (somewhere between zero and 93 million tons), and Tertiary waste rock is not considered whatsoever in the site water quality model (Knight Piesold, 2019), as discussed in Section 4.1.

3 Proposed waste rock management strategies underestimate the risk of using acid generating and contaminant leaching materials as construction fill

Proposed mining activities are estimated to generate at least 93 million tons of waste rock during pre-production and production (US Army Corps of Engineers, 2020a). PLP is proposing to contain PAG waste rock in the PTSF and use non-PAG waste rock as construction material in embankments containing the BTSF. Unlike the PTSF, the proposed BTSF and associated seepage collection ponds are unlined, allowing contact waters to easily seep into aquifers and potentially migrate off site. **It is therefore critical that non-PAG (and non-contaminant leaching) waste rock be accurately characterized as such to understand the risk of on- and off-site water quality impacts. My review found that PLP's waste rock segregation plan is inadequate because it relies on a site-specific method for discerning PAG from non-PAG rock that does not align with best management practices, and no plan is proposed to discern contaminant-leaching from non-contaminant leaching rock.**

3.1 Unsupported method for discerning PAG and non-PAG waste rock

PLP proposes to classify PAG and non-PAG wastes in the field using acid base accounting. SRK quantified neutralizing potential (NP) and acid potential (AP) from humidity cell test data.⁹ Results showed that sulfide-rich Pre-Tertiary rocks have lower NP:AP ratios than Tertiary rocks. SRK concluded that a critical threshold of NP:AP = 1.4 may be used to classify rocks as PAG or non-PAG. That is, rocks with NP/AP > 1.4 (mostly Tertiary) will be classified as non-PAG and rocks with NP/AP < 1.4 (mostly Pre-Tertiary) will be classified as PAG.

An NP:AP of 1.4 is not a sufficiently conservative threshold for distinguishing PAG from non-PAG waste rock. Although there is no established standard for NP:AP thresholds to identify PAG wastes, most guidelines recommend more conservative thresholds. For example the International Network for Acid Prevention recommends a ratio of 2 (INAP, 2009), Prince & Errington (1998) recommended a conservative screening criterion of 4, and Scharer et al. (2000) showed that NP:AP as high as 5 may become acidic in the long-run. Relative to these sources, PLP's critical NP:AP ratio for waste rock segregation is too low.

Comments from the U.S. EPA also expressed concern regarding PLP's PAG vs. non-PAG waste rock segregation technique. Specifically, one of EPA's comments (EPA, 2020) on Section 3.18 Water and Sediment Quality, subsection 3.18.1.1., page 3.18-3 reads:

"The site-specific value of 1.4 is an important number because it would be used to segregate PAG from non-PAG materials. We appreciate the additional information provided in SRK 2019 to support the calculation of the 1.4 value. We note that there are several factors that can affect the calculation of neutralizing potential to acid producing

⁹ SRK's calculation of neutralizing potential assumes that carbonate minerals are providing the neutralizing potential. However, PLP's mineralogy tests show that very few carbonate minerals are found in waste rock from the Pebble deposit, calling into question the basis of the proposed PAG v. non-PAG waste segregation plan. The paucity of carbonate minerals is discussed further in Section 2.4 of this review.

ratios (MP/AP) and result in the predictions that differ from conditions encountered during operations.

We continue to recommend, given uncertainties in the NP/AP calculations, that a more conservative ratio (such as 2 or 3) be used to differentiate PAG from non-PAG.”

EPA’s comments reflects the experimental nature of using an NP:AP segregation threshold of 1.4 and recommends using a more conservative threshold (such as 2 or 3).

PLP’s own geochemical tests show that Tertiary rock samples, considered to be non-PAG, have a potential to generate acid and leach metals and other mine-related contaminants, such as selenium. For example, HCT results for Tertiary samples 220366-TY-OPERATING, 221502-TD-OPERATING, and 104472-TC-OPERATING show that pH continuously declines over more than 600 days (PLP, 2011, Appendix 11G). These tests are discussed in greater detail in Section 3.2.

Changes from DEIS to FEIS:

- No changes have been made to revise protocols for separating PAG from non-PAG waste rock. PLP continues to rely on an experimentally determined and insufficiently conservative NP:AP ratio of 1.4.
- Appendix N of the FEIS appears to imply that all waste rock extracted during production will be PAG, but the height of the embankments in the PTSF, which would hold all PAG waste rock during operations, are lower.

Assumption consequence:

- Improper segregation of PAG and non-PAG waste rock increases the likelihood of PAG and contaminant leaching (CL) rock being used as construction fill, ultimately increasing the risk that mine-influenced waters will contaminate groundwater and surface water.

Recommendation:

- Revise waste management plan under a more conservative NP:AP ratio that is in-line with professional standards.

3.2 No proposed plan for discerning contaminant from non-contaminant leaching rock Appendix N of the FEIS states that PAG and ML waste rock will be stored in the PTSF until closure (US Army Corps of Engineers, 2020a, section 3.2.3) . While PLP proposes a method, although flawed, to distinguish PAG from non-PAG rock, **no methods are presented in the FEIS to distinguish CL from non-CL rock**. This results in an implicit assumption throughout the FEIS that PAG rock is CL rock, and non-PAG rock is non-CL rock. **If CL waste rock is assumed to be non-CL and is improperly used and managed on site, runoff and infiltration from facility embankments may have higher than expected concentrations of chemical constituents that are toxic to aquatic life in low concentrations – such as copper, selenium, arsenic, and mercury.** Moreover, non-PAG tailings and waste storage facilities (BTSF and associated seepage ponds) are unlined, presenting a potential hydrologic connection between the BTSF and groundwaters, through which pollutants may be transmitted.

PLP’s own geochemical tests shows that non-PAG (Tertiary) waste rock leaches metals, sulfate, and other mine-related contaminants. Shake flask test results of Tertiary waste rock presented in the

Environmental Baseline Data Report, Figure 11-42, show elevated concentrations of selenium and arsenic. Humidity cell testing of Tertiary waste rock shows that it has the potential to generate acid and leach contaminants over long periods of time. HCTs for two Tertiary waste rock samples from Pebble West zone were continued for more than 2500 days, longer than any other Tertiary waste rock samples (Supplemental Environmental Baseline Data Report, Appendix 11E Graph 1 of 37, samples 4157-439-471 and 4292-514-430). These samples show a progressive decline in pH from day 1000 onwards (Figure 4). While the pH of the leachate does not drop below 6, the rate of change in pH trends in a concerning direction, especially considering the FEIS site water quality model ignores inputs from Tertiary waste rock.

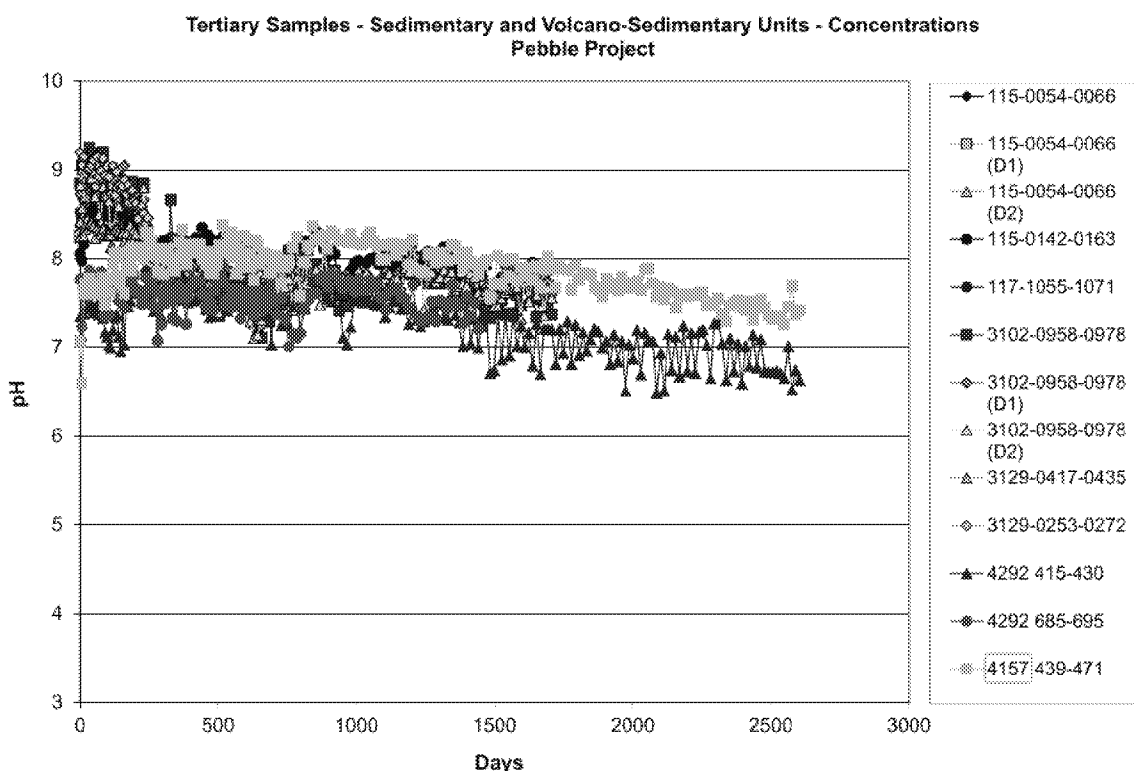


Figure 4. Humidity Cell Test results for Pebble West Zone Tertiary samples show that pH continuously decline for two samples analyzed beyond 2000 days. The graph was taken from the Supplemental Environmental Baseline Data Report, Appendix 11E.

Figure 5 shows the copper leach rates for the Tertiary samples shown in Figure 4. Increasing copper leach rates occurs coincidentally with the drop in pH observed in samples 4157-439-471 and 4292-514-430 (see Figure 5). From day 1500 or 2000 onwards, copper leach rates increased. The rate of change in copper release rates increases with time at the tail end of the test, suggesting that copper leaching from Tertiary waste rock may become progressively more concerning with time.

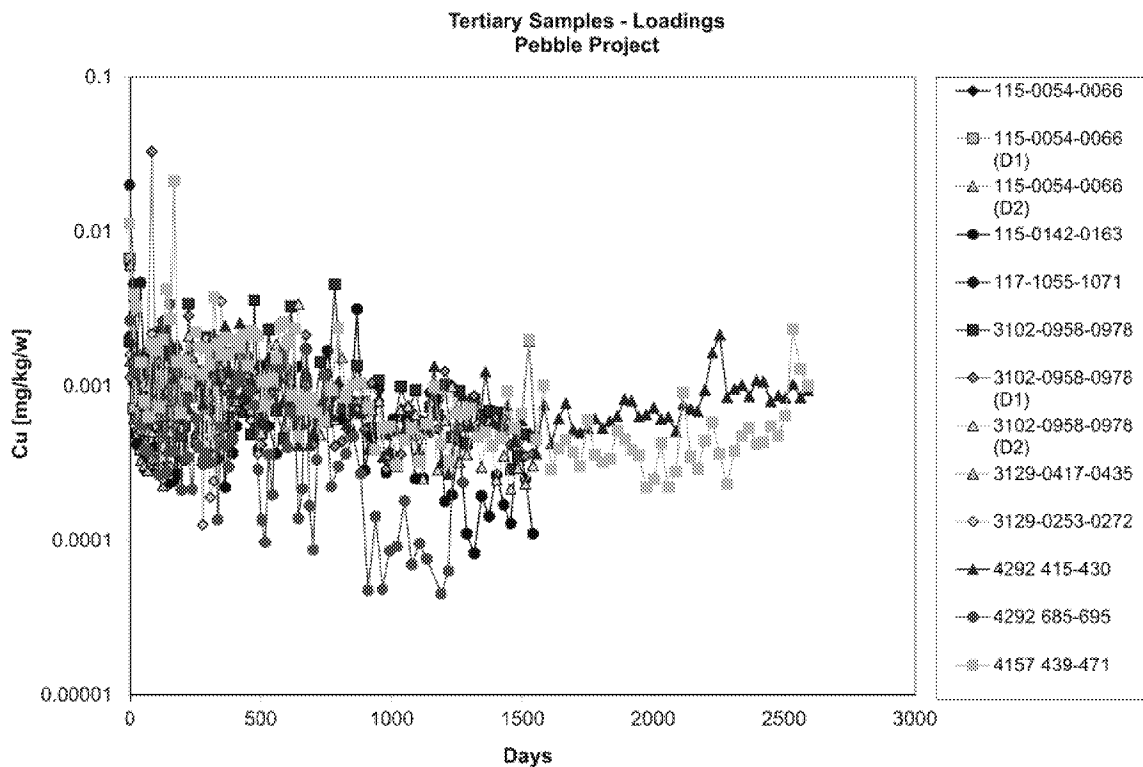


Figure 5. Humidity cell test results for Pebble West Zone Tertiary rock show increasing copper leach rates for two samples analyzed beyond 2000 days. The graph was taken from the Supplemental Environmental Baseline Data Report, Appendix 11E.

HCT results from Tertiary waste rock samples from the Pebble East Zone are also concerning. Data show that some Tertiary waste rock samples become progressively more acidic with time (Figure 6). Three samples generate leachate with pH values less than 4 at the conclusion of the test. Coincident with the drop in pH for samples 104472-TC-OPERATING, 221502-TD-OPERATING, and 220366-TY-OPERATING, is a rise in metal and metalloid leach rates. For example, copper leach rates for these samples increase logarithmically through time (Figure 7). Although these waste rock samples are geologically classified as Tertiary, which are assumed to be non-PAG, they generated acid and leached contaminants. These results highlight why classifying waste rock by geologic age is an inadequate approach for discerning PAG v. non-PAG and CL vs. non-CL wastes.

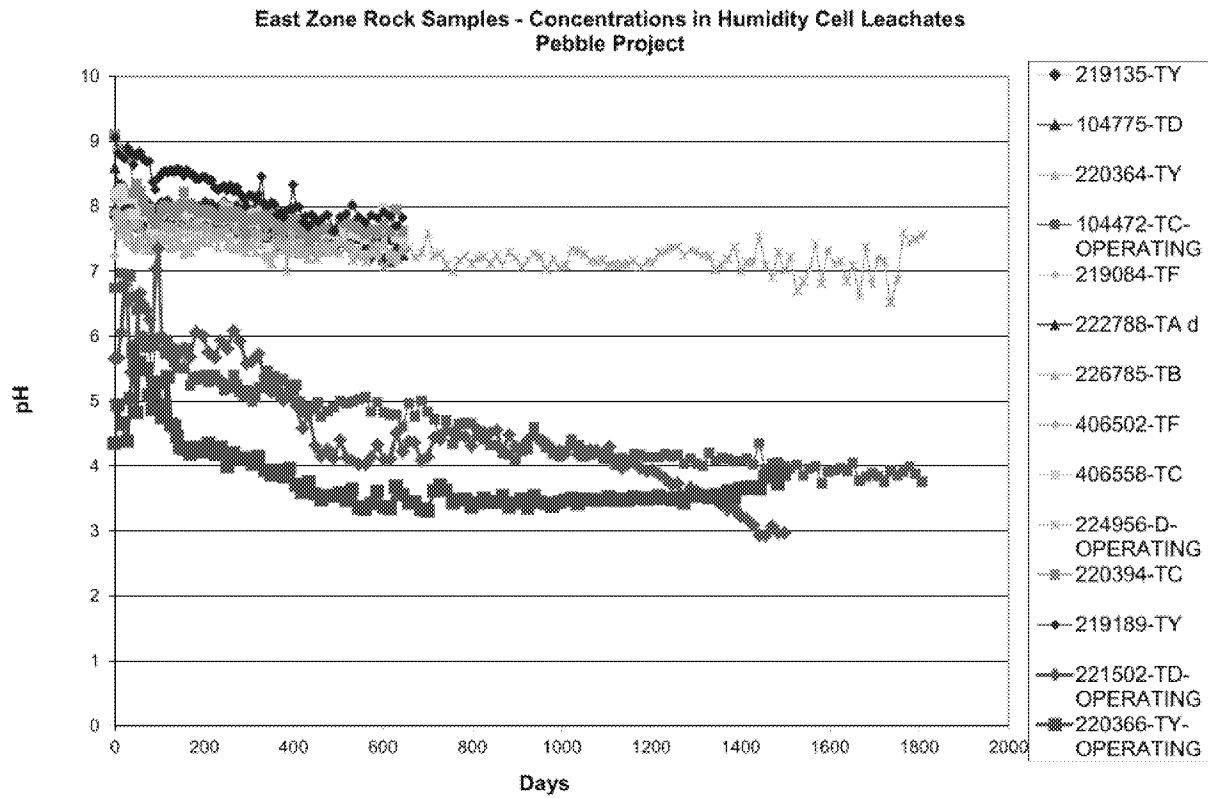


Figure 6. Humidity Cell Test results for Tertiary waste rock samples from the Pebble East Zone show that pH drops below 6 for three Tertiary samples, indicating that these samples are PAG. The graph was taken from the Supplemental Environmental Baseline Data Report, Appendix 11E.

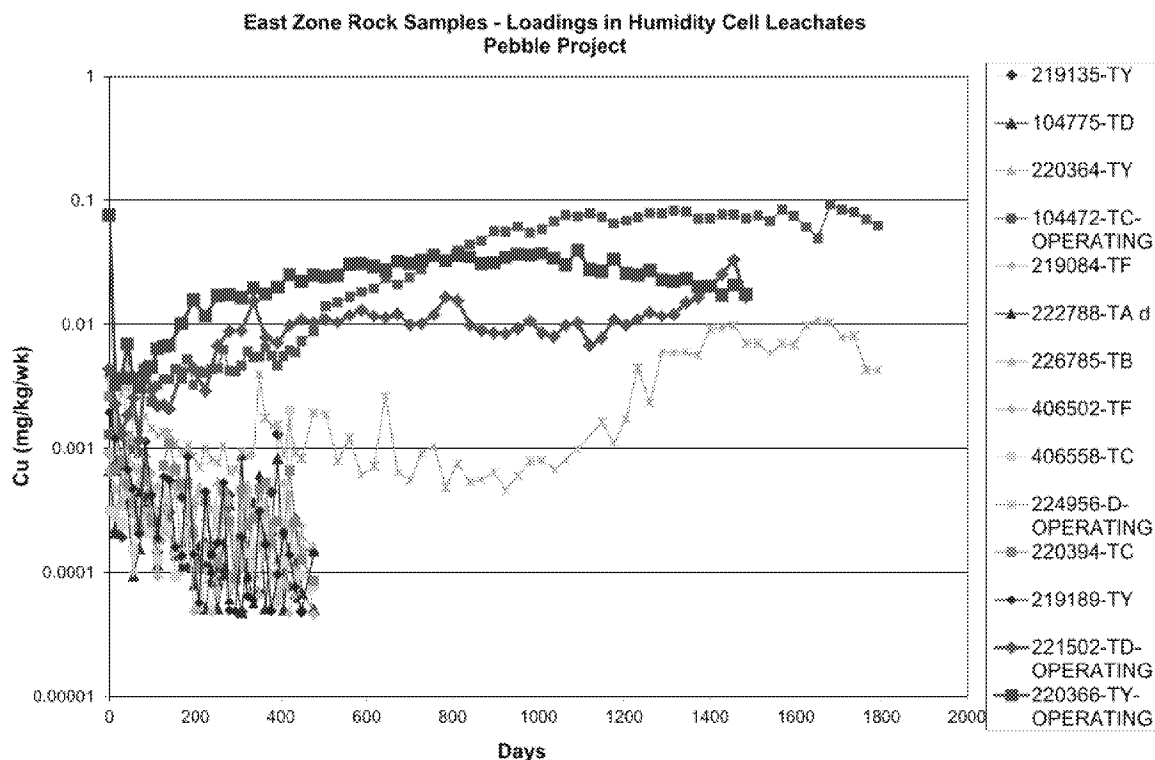


Figure 7. Humidity Cell Test results for Tertiary samples from the Pebble East Zone show that copper leach rates increase sharply throughout the test duration in four samples analyzed beyond 600 days. The graph was taken from the Supplemental Environmental Baseline Data Report, Appendix 11E.

Changes from DEIS to FEIS:

- No changes have been made to propose a protocol for segregating CL from non-CL waste rock. The FEIS continues to assume that non-PAG rock will not leach contaminants.
- Tertiary waste rock has been eliminated as a source term from the site water quality model.

Assumption consequence:

- PLP proposes to use non-PAG waste rock as construction fill, especially in constructing BTSF embankments. Improper identification and segregation of CL and non-CL rock increases the likelihood that construction fills will leach metals and other mine related contaminants.
- Relying on geologic age (i.e. Tertiary or Pre-Tertiary) to identify and separate CL from non-CL rock risks increasing source contaminant releases throughout the site. PLP's own geochemical testing shows that Tertiary waste rock leaches contaminants and generates acid over longer periods of time.

Recommendation:

- Revise Appendix N of the FEIS to include a plan for reliably identifying CL from non-CL waste rock.

4 Flawed water quality model source terms increase the risk of under designing water treatment plants

PLP's consultants constructed a water quality computer model to simulate expected contaminant concentrations in water treatment plant influent. Simulated contaminant concentrations and loads are used to design water treatment plants. **If predicted input values are inaccurate, water treatment facilities may be under designed and incapable of treating mine water to the level required for the safe release into streams. My review found several shortcomings in the site water quality model and changes to model source terms from the DEIS to the FEIS.**

This section highlights three particularly concerning shortcomings in the site water quality model¹⁰:

1. Tertiary rock runoff and seepage is not considered in the model, whatsoever.
2. Constituent concentrations for the "Quarried Rock (Dams)" source have been lowered by several orders of magnitude.
3. The runoff/infiltration water flux from subaerially stored PAG waste rock into the PTSF is unrealistically low.
4. PLP concludes that Influent to WTP 1 during operations and WTP 3 during closure phase 1 will have neutral pH, despite the predicted acidity being greater than the alkalinity.

Additionally, I call out all apparent changes to the water quality model source terms that occurred between the DEIS and FEIS.

A bit of background on the water quality model is needed for context. The site water quality model is constructed in GoldSim, a commonly used piece of software for simulating water balance and the chemistry of mine site waters. The Pebble Project site water quality model can be broadly classified as an "end-member-mixing" model, where contaminant sources and transfers are represented by a series of flow rates and concentrations. The model ensures that mass is conserved at the site-level (i.e. contaminant mass in = contaminant mass out) and predicts the steady-state chemistry of critical water storage facilities, such as tailings impoundment supernatant, seepage collection ponds, and water management ponds. Critically, PLPs water quality model does not account for transient hydrologic conditions or chemical reactions. It simply simulates the steady state mixing of waters of varying chemistry and flows without considering any chemical reactions that could occur during mixing.

In practice, the modeling effort appears to have been a two-step process. First, SRK (2018a & 2019) predicted the water quality of various contaminant sources at the mine site. The development and specification of these contaminant sources can be found in (Knight Piesold, 2019) Appendices D1 and D2, which are memos written by SRK. Second, Knight Piesold used the source term chemistry provided by SRK for specific model flowpaths. Additionally, Knight Piesold determined flow rates for each model flowpath. It is essential to understand the two-step process of the water quality model development because contaminant sources identified and specified by SRK are not necessarily implemented in the model by Knight Piesold.

¹⁰ These are not the only three concerns with the water quality model. In addition to these enumerated concerns, the water quality model ignores subaqueous leaching in the PTSF and BTSF and likely underestimates the subaerial waste rock contaminant leaching rates. These concerns are discussed in section 2 of this report.

4.1 Tertiary (non-PAG) waste rock is not included in PLP's site water quality model

The potential for Tertiary waste rock to leach contaminants, as discussed in Section 3.2 of this review, is particularly concerning because Tertiary waste rock has been eliminated as a source-term in the Water Balance and Water Quality Model Report supporting the FEIS (Knight Piesold, 2019, Table D3.1). The Project Description, Appendix N, of the FEIS clearly states that non-PAG waste rock will be used to construct embankments around the BTSF. However, Tertiary waste rock has been removed from the revised water quality modeling document, specifically Table 1 in Appendix D2 of (Knight Piesold, 2019). A source term for Tertiary waste rock was reported in documentation supporting the DEIS, specifically Table 4 in (SRK, 2018a). No justification is provided for the omission of Tertiary waste rock as a contaminant source in the Water Balance and Water Quality Model Report (Knight Piesold, 2019).

Despite the omission of Tertiary waste rock in Table 1 of Appendix D2 of the revised Water Balance and Water Quality Model Report, it is unclear if Tertiary waste rock was ever represented in the mine site water quality model. Table B1.2 in of the Pebble Mine Site Operations Water Management Plan (Knight Piesold, 2018b) shows that only "Quarried Rock Fill (Dams)" was considered as a source where Tertiary waste rock should have been used (BTSF embankments). There is no representation of Tertiary waste rock in the site water quality model, even though Tertiary waste rock is planned to be used as embankment construction materials (US Army Corps of Engineers, 2020a). The elimination of Tertiary waste rock as a source term is concerning because PLP's own testing shows that Tertiary waste rock has a potential to leach contaminants, especially selenium, as described in Section 3.2 of this review. Surely Tertiary waste rock will affect site water quality conditions, yet there is absolutely no mention of it as a source term in site water quality models.

4.2 Assumed runoff/infiltration flows from PAG waste rock are too low and poorly defined

PLP plans to store PAG waste rock subaerially on the banks of the PTSF for up to 1.5 years before it is submerged by PTSF pond waters (US Army Corps of Engineers, 2020a). While exposed, waste rock will be subjected to periodic rainfall and snowmelt events. Some portion of precipitated water will runoff directly into the PTSF, another portion will infiltrate and slowly seep into the PTSF via shallow subsurface flow, and the remainder will evaporate back into the atmosphere¹¹.

In acknowledgement of this process, the site water quality model has been revised to include two new PAG rock source terms: "Leached WR" and "PAG WR," where "Leached WR" will generate acid and leach contaminants immediately upon placement in the PTSF. The ratio of "Leached" to "PAG" waste rock is assumed to be 37:63. These new terms affect flowpath #78, "Runoff/Infiltration from Temporarily Exposed Waste Rock" in the Water Balance and Water Quality Model Report (Knight Piesold, 2019, Table A.1). Knight Piesold appoints a flowrate of <1 cfs to flowpath 78 under all climate scenarios. For context this amounts to anywhere from 50% to 14% of the annual quantity of precipitation falling directly onto the PTSF supernatant pond, though it is hard to say because the model documentation does not specify how much below 1 cfs the flows associated with flowpath 78 are.

¹¹ The bottom of the proposed PTSF is lined to prevent contact waters from leaking into the shallow aquifer. However, it is important to note that all liners leak and have a prescribed hydraulic conductivity. The water balance of the PTSF will not be as tight as it is described in the FEIS.

A simple calculation shows that the annual flow rate associated with flowpath 78 in the Water Balance and Water Quality Model Report is underestimated. I start with two reasonable assumptions: 1) waste rock piles have a runoff ratio of 70% (i.e. 30% of rain and snow falling onto waste rock piles are evaporated/sublimated) and 2) waste rock piles account for 25% of the PTSF area, or about 0.25 square miles (visually approximated from Knight Piesold (2019), Figure 1.1). It follows that under “relatively wet conditions”, or 91 inches of annual precipitation, the annual average flow rate from exposed waste rock piles is approximately 2 cfs. This is surely greater than “<1 cfs” flow rate associated with flowpath 78 in the FEIS water quality model.

Underestimating the annual flow rate associated with flowpath 78, “Runoff/Infiltration from Temporarily Exposed Waste Rock,” reduces the chemical loading from PAG waste rock into the PTSF and therefore underestimates concentrations reporting to the WTPs. Moreover, not specifying the exact flow rate used for flowpath 78 (vaguely defined as < 1cfs) makes it difficult to quantify the chemical loadings. For example, the prescribed flow rate could be 0.0001 cfs or 0.9999 cfs, and we would have no way of knowing based on the information provided in the FEIS and supporting documentation.

4.3 “Quarried Rock (Dams)” source term concentrations have been lowered
PLP lowered constituent concentrations associated with the “Quarried Rock (Dams)” source term in the site water quality model (Knight Piesold, 2019, Appendix D2) from the DEIS to the FEIS (Table 2). SRK set the chemistry of this source term equal to non-contact surface water (Knight Piesold, 2019, Appendix D2 Table 1). This change lowered concentrations of key constituents by several orders of magnitude:

Table 2. Comparison of concentrations of select constituents associated with the Quarried Rock (Dams) water quality model source terms in the DEIS and the FEIS. Source: Knight Piesold, 2019, Appendix D2.

Constituent	DEIS concentration (mg/L)	FEIS concentration (mg/L)
Sulfate	2400	7.8
Copper	0.16	0.0021
Selenium	0.055	0.00041
Iron	1.7	0.55
Sodium	110	2.4
Potassium	36	0.37
Molybdenum	9.8	0.00051

SRK justified this change “based on characteristics of quarry rock indicating low sulfide content” (Knight Piesold, 2019, Appendix D2, Section 3). However, only minimal geochemical testing was conducted on quarry rock and some of the tests suggest that sulfide content can be greater than 4% (SRK, 2018b). SRK never conducted HCTs on the quarry rocks.

This change assumes that embankment runoff is no different than runoff from undisturbed areas. This assumption is inappropriate because embankment structures will be built from freshly exhumed quarry rock and Tertiary waste rock that will be exposed to abundant quantities of oxygen and water for the first time. PLP’s own geochemical testing shows that Tertiary waste rock can generate acid and leach contaminants (Section 3.2 of this review), and relatively little testing was conducted to assess the contaminant generating potential of quarried rock (SRK, 2018b). **It is reasonably foreseeable that runoff**

and seepage water emanating from BTSF embankments will have higher contaminant concentrations than undisturbed runoff. This would result in higher than expected contaminant concentrations reporting to site water treatment plants and an increased risk of environmental degradation if treatment plant effluent was inadequately treated and discharge to streams.

4.4 Acidity exceeds alkalinity, yet pH is neutral

PLP projects that inflows to WTP #1 during operations and WTP #3 during closure phase 1 will have a pH between 7 and 8 (Water Balance and Water Quality Model Report, Appendix E). However, simulated acidity exceeds simulated alkalinity for these flows. This apparent logical lapse illustrates that it is unreasonable to conclude that the pH of all water bodies on the site will have a neutral pH.

Additionally, it is important to point out that the site water quality model cannot predict the pH of site waters. The water quality model is a simple end-member mixing model, that simulates chemical dilution and enrichment resulting from the mixing of various flowpaths. The water quality model does not simulate geochemical reactions that would affect pH. This is clearly stated in section 4.1.2 of the Water Balance and Water Quality Model Report (Knight Piesold, 2019), which lists the general approaches used to apply the geochemical source terms in the water quality model:

“pH values were not modelled” - (Knight Piesold, 2019, section 4.1.2)

The prediction that the pH of all site waters will be neutral (“7 to 8”) appears to be a baseless decision, rather than a data- and theory-informed conclusion.

4.5 An overview of water quality model source term changes from DEIS to FEIS

Table 3 presents a list of changes to water quality model source terms from the DEIS to the FEIS. This table contains changes discussed in Sections 4.1 and 4.3 of this review.

Table 3. Changes in water quality model source terms from DEIS to FEIS. Source terms for the DEIS are specified in (SRK, 2018a) and (Knight Piesold, 2019). Source terms for the FEIS are specified in (Knight Piesold, 2019). For convenience, both source term tables can be found in a single documents, (Knight Piesold, 2019).

Specific change	Reason for concern
Waste rock (group), Waste Rock (source), Tertiary (Sub-source) has been removed	PLP plans to use Tertiary waste rock as construction material in the Bulk Tailings Storage Facility main and southern embankments. Removing this term from the water quality source model assumes that the rock will have no impacts on water quality. This change is discussed in greater detail in section 4.1 of this review.
Other Rock (group), Quarried Rock Fill (Dams) (source), Non-Acidic (sub source) concentrations have been changed to represent non-contact surface water.	Quarried Rock Fill (Dams) accounts for a large portion of water flowing into BTSF seepage collection ponds and the main water management pond. Lowering constituent concentrations associated with this source term decreases chemical loads in the new water quality model. Indeed, contaminant source concentrations have been lowered by orders of magnitude. This change is discussed in greater detail in section 4.3 of this review.
Tailings (group), Bulk Tailings Water (source), supernatant (sub source) has been removed	No explanation is provided for this omission. Perhaps this was removed because it is a calculated term by the water quality model.
Tailings (group), LGO Leaching + reagent (source) has been removed	No explanation is provided for the omission and it is unclear what this source refers to.
The PTSF group has two new source terms: PAG WR & Leached WR, expressed in mg/L. These new terms replaced a single term: "PAG WR is 41% of facility area" with units of kg/year in the DEIS.	While these new source terms admit that some of the waste rock will generate acidic runoff immediately, there is no apparent influence on the pH of the PTSF. This change is discussed in greater detail in sections 4.2 and 2.4 of this review.
A new group has been added, called "PTSF – Decommissioning" with one source called "Exposed Waste Rock" and two sub sources, "Low Pyritic Tailings" and "High Pyritic Tailings"	These new source terms assume concentration values from the proprietary porphyry database, rather than from PLP's own kinetic tests. No explanation is provided as to why subaqueous column test results are not used to derive these source terms.
Open Pit Closure (group), Wall Runoff (source) has been removed	In the DEIS, Wall Runoff was the only acidic source term (Knight Piesold, 2018b, Tabld B1.1). Removing this term artificially eliminates a known source of acidic water in the water quality model.

5 References

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